EurJOC
European Journal of Organic Chemistry

Chemistry Europe
European Chemical Societies Publishing

Accepted Article

Title: Efficient thiophene synthesis mediated by 1,3-bis(carboxymethyl)imidazolium chloride: C-C and C-S bond formation

Authors: Patricia Gisbert and Isidro Manuel Pastor

To be cited as: *Eur. J. Org. Chem.* 10.1002/ejoc.202000484

Link to VoR: https://doi.org/10.1002/ejoc.202000484

WILEY-VCH

WILEY-VCH

FULL PAPER

Efficient thiophene synthesis mediated by 1,3-bis(carboxymethyl)imidazolium chloride: C-C and C-S bond formation

Patricia Gisbert,[a] and Isidro M. Pastor*[a]

[a] Dr. P. Gisbert, Dr. I. M. Pastor
Organic Chemistry Department and Instituto de Síntesis Orgánica (ISO)
University of Alicante
Apdo. 99, 03080 Alicante, Spain
E-mail: ipastor@ua.es
https://orcid.org/0000-0002-8271-0641

Supporting information for this article is given via a link at the end of the document.

Abstract: Thiophene derivatives have been prepared by means of a functionalized imidazolium salt [1,3-bis(carboxymethyl)imidazolium chloride] acting as a catalyst. The heterogeneous catalyst has allowed to carry out the reactions with no solvent or inert atmosphere. Different aryl methyl ketones have reacted with elemental sulfur to selective produce 2,4-substituted thiophenes. Furthermore, the reaction of sulfur with cyclic ketones has enabled the preparation of polycyclic compounds. This protocol is simple and effective for preparing thiophene derivatives, even in a preparative scale. The thiophene synthesis described presents remarkable sustainability with an E-factor of 7.4, the solvent-free conditions being crucial for this feature. The catalyst is straightforwardly prepared, and it is easily separated from the reaction mixture, being possible its reuse.

Introduction

Sulfur-containing heterocycles are an important class, among other heterocyclic compounds, in the field of pharmacology.[1] Among them, thiophene derivatives have shown interesting applications in the field of medicinal chemistry. Compounds containing a thiophene unit have shown antimicrobial activity, anticancer activity, antioxidant activity, anti-inflammatory activity, anti-urease activity, anticonvulsant activity, and antithrombic activity.[2] In addition, thiophene-derived compounds have a significant role in the development of organic semiconductors, which are useful in the advance of organic electronics.[3] Therefore, the progress and improvement of methodologies that allow the preparation of these heterocyclic derivatives are of interest, both from an applied and fundamental point of view. The principal synthetic methodologies can be divided into two different categories, (a) functionalization of a formed thiophene ring,[4] and (b) ring formation from acyclic precursors. Among the most conventional protocols are the Paal-Knorr synthesis (reaction of 1,4-dicarbonyl compounds with a sulfur reagent),[5] the Gewald synthesis (a multicomponent reaction between a carbonyl compound, an activated nitrile and sulfur, in the presence of a base, to form substituted 2-aminothiophenes),[6] the Fiesselmann synthesis (a condensation, in the presence of a base, of thioglycolic acid derivatives with acetylenic esters),[7] and the Hinsberg synthesis (a reaction of a thiodiglycolate and a 1,2-dicarbonyl compound under basic conditions).[8]

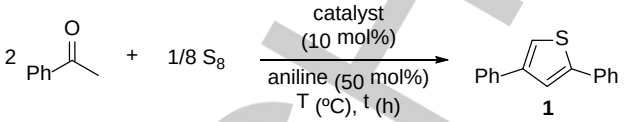
From a green chemistry perspective, the construction of functionalized molecules with complex structures from readily available reagents is of great significance, drawing the attention of organic chemists. It is desirable to find more sustainable synthetic processes for pharmacologically active compounds, improving the environmental impact during their industrial production.[9] New and efficient protocols for the construction of substituted thiophenes are still desirable to achieve this aim. Thus, microwave-assisted thiophene synthesis has been described for different protocols, such as Paal-Knorr condensation[10] and Gewald reaction.[11] An efficient and simple copper catalyzed route for the synthesis of di-, tri- and tetrasubstituted thiophenes, with excellent yields, has been reported starting from 1,4-diiodo-1,3-dienes and potassium sulfide.[12] Some methodologies use different sulfur reagents (such as K_2S,[13] KSCN[14] or KSAc)[15] that decrease the atomic economy of the process. Therefore, the use of elemental sulfur (S_8) is a more sustainable alternative for preparing sulfur-containing compounds, being considered a cheap and environmentally friendly reagent.[16] Recently, it has been described a base-promoted (*t*-BuONa) cyclization of 1,3-diynes in the presence of sulfur to form 3,4-diarylsubstituted thiophenes.[17] A simple and effective method for the formation of π-system fused-thiophene derivatives has been reported, reacting arylethynyl substituted polycyclic arenes with elemental sulfur via C-H activation.[18] The preparation of 2,3,5-trisubstitutedthiophenes have been achieved by the reaction between arylacetaldehydes and 1,3-dicarbonyl compounds in the presence of elemental sulfur,[19] and 2,4-diarylthiophenes has been obtained from a redox condensation between acetophenone derivatives and sulfur.[20] These protocols need the use of organic solvents (such as *N*,*N*-dimethylformamide and dimethylsulfoxide),[17-19] and the use of inert atmosphere.[20] Therefore, the use of more benign reaction media is an interesting improvement to obtain more sustainable processes. Recently, the use of alternative solvents such as deep eutectic solvents (DES) has proved to be very useful[21] albeit it is even better to carry out organic transformations under solvent-free conditions.[22] Aware of

this, our research group has focused on the development of synthetic catalytic processes in the absence of solvents. Thus, metal-organic frameworks (MOF) have been used, as heterogeneous catalysts under solvent-free conditions,[23] to carry out the preparation of amides,[24] and the synthesis of quinoline derivatives.[25] Iron-based Lewis acidic imidazolium salts have been employed as catalysts, under neat conditions, in preparing thiomides,[26] and the selective synthesis of 2-allylanilines, 4-allylanilines or quinolines starting from the same starting materials.[27] More recently, we have explored the use of carboxy-functionalized imidazolium halides, which are ionic organic solids (IOS), as heterogeneous catalysts, being possible to perform reaction without solvents. Thus, *N*-allylanilines,[28] quinoline and acridine derivatives[29] have been prepared by the use of 1,3-bis(carboxymethyl)imidazolium chloride (**bcmim-Cl**). The imidazolium salt presents different moieties which are important for the catalytic activity due to favorable interactions with the reactants, which are crucial in the absence of a reaction solvent. Based on that, we considered that this type of catalyst could favor the formation of thiophenes via a more sustainable protocol without any solvent and/or the need for inert atmosphere. Herein, we described our findings in the evaluation of 1,3-bis(carboxymethyl)imidazolium chloride (**bcmim-Cl**) as a metal-free heterogeneous catalyst for the preparation of thiophene derivatives.

Results and Discussion

Initial efforts were focused on the optimization of the reaction conditions between acetophenone and elemental sulfur as model reactants. The reaction was carried out, under solvent-free conditions, using 1,3-bis(carboxymethyl)imidazolium chloride (**bcmim-Cl**, 10 mol%) as the catalyst at 80 ºC, in the presence of aniline. After 16 h, the expected 2,4-diphenylthiophene (**1**) was observed with a 13% conversion (Table 1, entry 1). The reaction failed when lower temperatures (60 ºC) were used providing the expected thiophene in less than 5% conversion. As expected, the reaction outcome was improved by increasing the temperature, obtaining thiophene **1** with 68% conversion at 100 ºC, and with full conversion at 120 ºC (Table 1, entries 2 and 3). At this temperature (120 ºC), the reaction time could be reduced until 8 h without observing any decrease in the conversion (Table 1, entry 4), and the conversion remains at high values even after 6 h (97%, Table 1, entry 5). It is worthy to mention that the product was isolated in 95% yield (Table 1, entry 5, footnote [b]), proving the effectiveness of the protocol described. Moreover, **bcmim-Cl** proved to be crucial for the reaction to proceed, since the non-catalyzed reaction gave no conversion after 6 h (Table 1, entry 7). Reducing the amount of the catalyst to 5 mol% resulted in lower conversion (42%) after 6 h (Table 1, entry 8). Moreover, it was observed that the reaction catalyzed by the zwitterionic imidazole derivate **bcmim** (10 mol%) gave only 15% conversion to the thiophene **1** (Table 1, entry 9), proving that the presence of the counterion chloride is significant during the catalytic process, as previously observed for other transformations.[29] In addition, the reaction under microwave heating was also tested since it has been described to be a sustainable alternative.[30] Thus, the reaction was performed under microwave irradiation at 120 ºC (constant temperature using 80 W of initial potency) during 1 h, giving the desired product in 82% conversion (Table 1, entry 10, footnote [c]). Extending the reaction time, up to 90 minutes, did not result in a significant improvement (85% conversion), so conventional heating was chosen to continue.

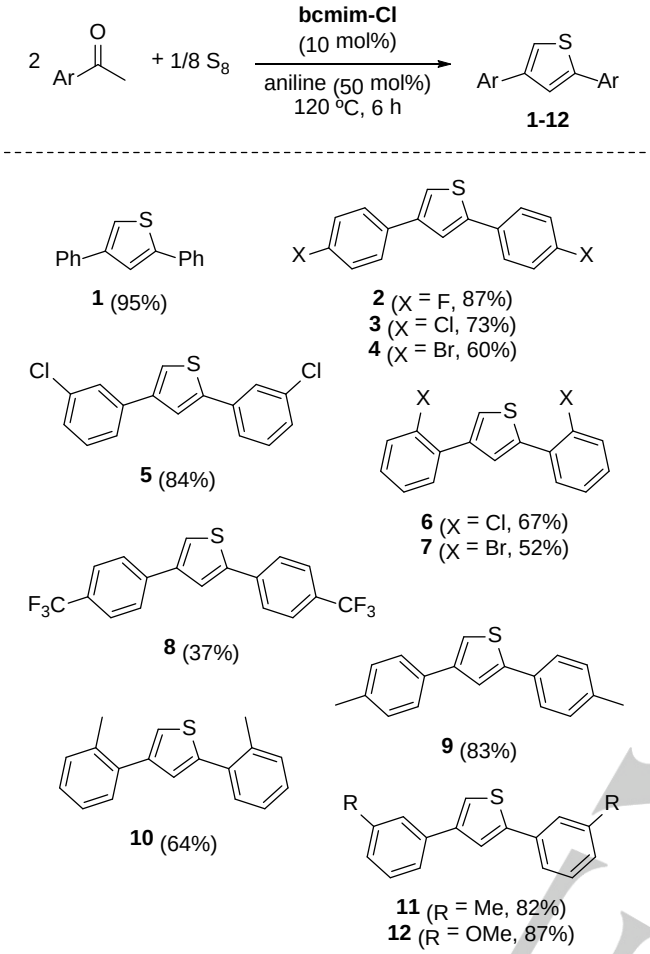
Table 1. Optimization of the reaction conditions[a]



Entry	Catalyst (mol%)	Time (h)	Temp. (ºC)	Conversion (%)
1	**bcmim-Cl** (10)	16	80	13
2	**bcmim-Cl** (10)	16	100	68
3	**bcmim-Cl** (10)	16	120	>99
4	**bcmim-Cl** (10)	8	120	>99
5	**bcmim-Cl** (10)	6	120	97 (95)[b]
6	**bcmim-Cl** (10)	4	120	87
7	No catalyst	6	120	<1
8	**bcmim-Cl** (5)	6	120	42
9	**bcmim** (10)	6	120	15
10	**bcmim-Cl** (10)	1[c]	120	82 (76)[b]

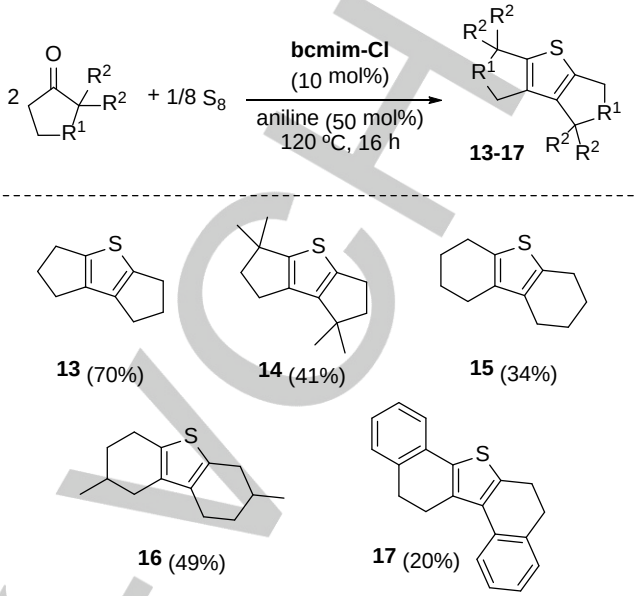
[a] Reaction conditions: acetophenone (0.5 mmol), sulfur (0.75 mmol) and catalyst (10 mol%), aniline (50 mol%). Conversion determined by GC analysis. [b] In parenthesis, yield of the isolated product after purification by column chromatography. [c] Reaction performed using microwave irradiation as heating source (constant temperature, using 80 W of initial potency).

To find the scope of the reaction using the **bcmim-Cl** as the catalyst, several acetophenones were evaluated, the expected 2,4-diarylthiophenes **1-12** being exclusively formed (Scheme 1). Acetophenones bearing electron-withdrawing groups, such as halogens, provided the corresponding thiophenes, which were isolated in good yields, regardless of the position of the substituent. Thus, 4-halophenyl methyl ketones reacted with sulfur to form thiophenes **2-4** with yields in the range of 60-87% (Scheme 1). Likewise, 3-chlorophenyl methyl ketone produced compound **5** with 84% yield (Scheme 1). In the case of 2-chloro- and 2-bromoacetophenone, the products **6** and **7** were obtained with 67% and 52% yield, respectively, being slightly lower compared with thiophenes **3**, **4**, and **5** probably due to steric hindered. In addition, it was observed that the presence of a strong electron-withdrawing group, such as trifluoromethyl, resulted in the formation of the corresponding product **8** with a 37% yield (Scheme 1). Interestingly, the presence of electron-donating substituents, such as methyl and methoxy, led to the formation of the thiophenes **9-12** with comparable yields as the electron-withdrawing groups (Scheme 1). Similarly, the substituent in *ortho*-position hampered the formation of the thiophene resulting in lower yield (compare thiophene **10** with **9** and **11**, Scheme 1). In general, these results demonstrate the robustness of the protocol described with different aryl methyl ketones.



Scheme 1. Scope evaluation of acetophenones for the synthesis of thiophenes using **bcmim-Cl**. Reaction conditions: acetophenone (1 mmol), S (1.5 mmol), **bcmim-Cl** (0.1 mmol), aniline (0.5 mmol), 120 ºC, 6 h. In parenthesis, yield of the isolated product after column chromatography or preparative TLC.

The catalyzed protocol was next applied to different cycloalkanones to promote the formation of polycyclic derivatives. Thus, cyclopentanone led to the formation of the expected tricyclic thiophene derivative **13**, which was isolated in good yield (70%, Scheme 2), although it was necessary to extend the reaction time up to 16 h to complete the reaction. Furthermore, non-symmetrically 2,2-dimethylcyclopentanone gave solely the corresponding thiophene derivative **14** with moderate yield (Scheme 2). Likewise, cyclohexanone derivatives reacted via a sulfurative self-condensation leading exclusively to the formation of the corresponding thiophenes. Cyclohexanone and 4-methylcyclohexanone produced compounds **15** and **16** (Scheme 2). The reaction employing other cycloalkanones (i.e. 3-ethylcyclopentanone, 2-methylcyclopentanonte or tetrahydro-4*H*-thiopyran-4-one) afforded complex reaction mixtures. In these cases, the corresponding tricyclic products were formed, being unbearable to isolate. Nevertheless, the desired product **17** was isolated in 20% yield when α-tetralone was reacted with sulfur (Scheme 2).



Scheme 2. Scope evaluation of cyclic ketones for the synthesis of polycyclic thiophenes. Reaction conditions: ketone (1 mmol), S (1.5 mmol), **bcmim-Cl** (0.1 mmol), aniline (0.5 mmol), 120 ºC, 16 h. In parenthesis, yield of the isolated product after column chromatography or preparative TLC.

Furthermore, the imidazolium chloride **bcmim-Cl** was also examined as a catalyst, under neat conditions, on the thiophene preparation in preparative scale to prove the applicability of the process (Figure 1). Thus, acetophenone (5.8 mL, 50 mmol) and elemental sulfur (75 mmol) were reacted, at 120 °C for 6 hours, to afford the corresponding 2,4-diphenylthiophene **1** (Figure 1). After recrystallization, 4.5 g of pure product **1** (77% yield) was isolated. To better identify the environmental impact of the process, the *E-factor* was calculated considering the recrystallization step. An *E-factor* of 7.4 was obtained for the preparation of compound **1** (Figure 1), which is in the lower level of the reported range for Fine Chemical production in the industry.[9] Next, the recyclability of the catalyst was considered because the catalyst remains solid at the end of the reaction, the catalyst not being completely soluble during the reaction. Thus, the product was removed from the reaction media using ethyl acetate, which is considered as a recommended (or preferred) solvent in the selection guide of solvents for the pharmaceutical industry.[31] The remaining mixture was employed in the following cycle. The reaction was set again by only adding the starting materials. A slight decrease in the conversion was observed in the second cycle (Figure 1). The catalyst is reducing its activity in the successive cycles (Figure 1), probably due to the presence of sulfur by-products. Interestingly, it has recently established that acid treatment can easily perform the catalyst reactivation.[32]

Different control experiments were carried out to gain understanding into the reaction mechanism, which seems to proceed via an imine/enamine intermediate. Indeed, the reaction in the absence of aniline resulted in the recovery of the starting materials. Besides, the formation of the product got reduced to 61% by using less aniline (30 mol%). The use of other amines

with different nucleophilicity[33] (i.e. *p*-anisidine, hydroxylamine, and benzylamine) was tested. The reaction failed when *p*-anisidine or hydroxylamine was employed as an additive, being less effective in the promotion of the reaction. In the presence of benzylamine, the conversion to the product was incomplete (53%), observing also the imine intermediate. Furthermore, *N*,1-diphenylethanimine (**18**) could react with elemental sulfur in the presence of catalyst **bcmim-Cl** forming, as expected, thiophene **1** (Scheme 3a). Moreover, the reaction of acetophenone in the absence of sulfur, under standard conditions, produced *N*,1,3-triphenylbut-2-en-1-imine (**19**), as a result of the condensation of two acetophenone molecules. This imine **19** could be successfully converted in the thiophene **1** by treatment with sulfur in the presence of catalyst **bcmim-Cl** (Scheme 3b).

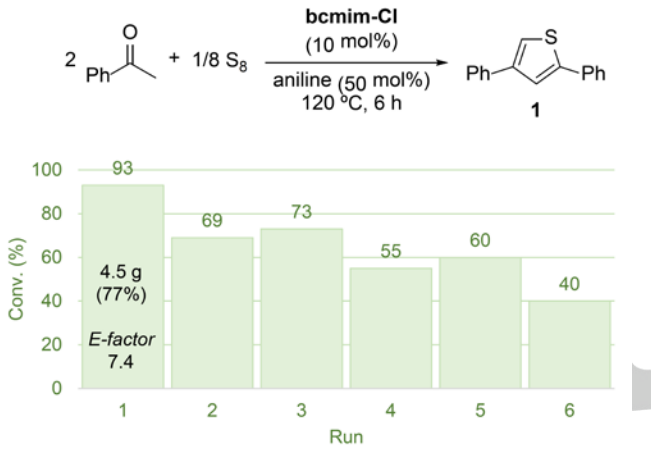
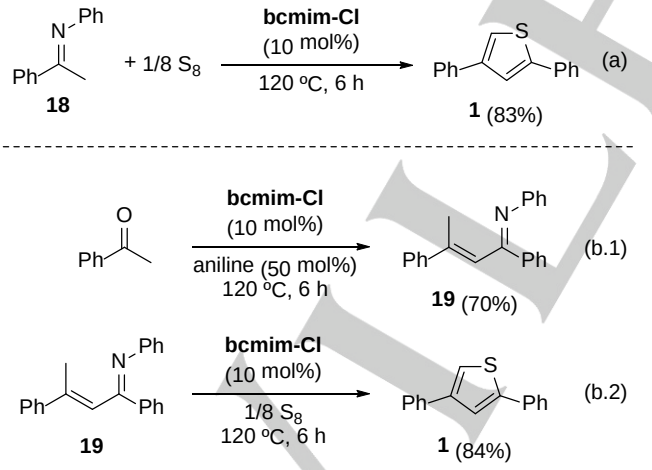
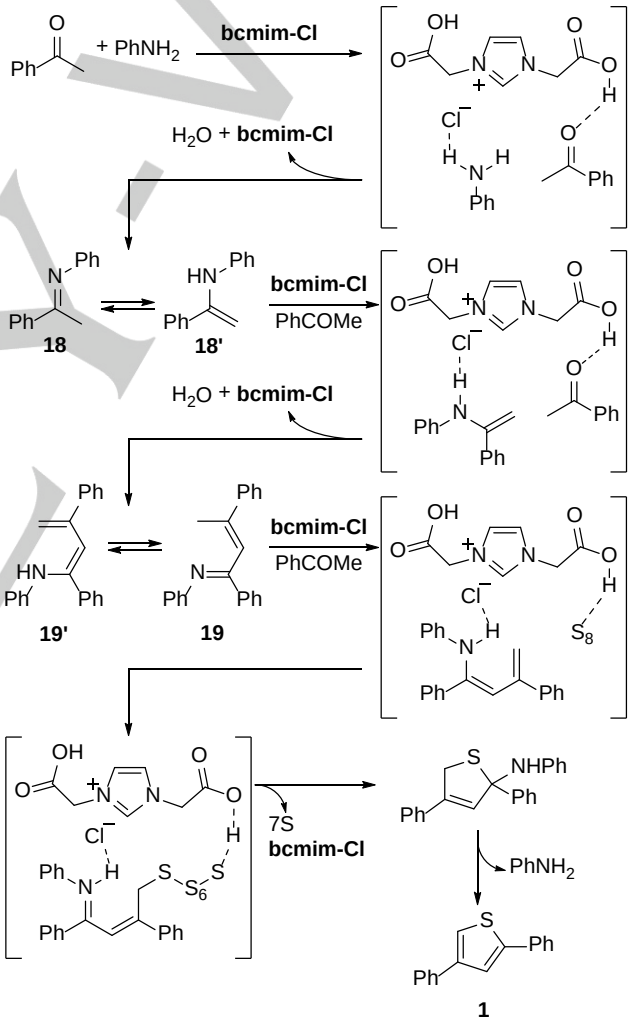


Figure 1. Reaction in multigram scale, *E-factor* in the preparation of **1**, and recycling of the catalyst.



Scheme 3. Control experiments. In parentheses, conversion determined by GC analysis.

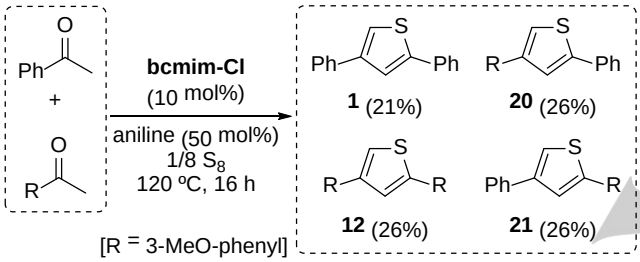
Based on that and the literature,[20, 28, 29] a possible reaction mechanism for the thiophene formation is depicted in Scheme 4. The structure of the catalyst (**bcmim-Cl**) provides favorable interactions during the catalytic process. As described,[29] the catalyst could help in the formation of the imine **18**, which is in equilibrium with the corresponding enamine **18'**, by interacting with the amine and the ketone (Scheme 4). Likewise, this enamine could react, using the catalyst, with another molecule of ketone to form imine **19** (Scheme 4). The extended enamine **19'**, in equilibrium with imine **19**, could act as nucleophile reacting with sulfur, being favored by their positive interactions with catalyst **bcmim-Cl** (Scheme 4). Then, the intramolecular cyclization reaction could form the expected thiophene by the elimination of aniline (Scheme 4). At this point, the reaction of acetophenone under the standard conditions was catalyzed with an imidazolium salt lacking the carboxylic acid [such as 1-(methoxycarbonylmethyl)-3-methylimidazolium chloride, **(mcm)mim-Cl**] to prove the relevance of the H-bonding in the mechanistic proposal. The reaction was performed under microwave irradiation getting thiophene **1** in 10% conversion after 1 h. This result is significantly lower compared with the obtained employing catalyst **bcmim-Cl** (Table 1, entry 10).



Scheme 4. Proposed mechanism for the thiophene synthesis meditated by the **bcmim-Cl**.

Next, the reaction of two different ketones with sulfur was considered as a more challenging transformation. To address this question, a reaction of sulfur, acetophenone, and 3-methoxyacetophenone was performed under the optimal reaction conditions, four thiophenes can be formed. Although the

conversion was excellent, it was not observed any significant difference in the selectivity process, being the four isomers formed in similar amounts (Scheme 5). As well, other combinations of ketones (such as acetophenone/4-hydroxyacetophenone, acetophenone/4-chloroacetophenone, acetophenone/4-methylacetophenone, and 4-chloroacetophenone/3-methoxyacetophenone) were reacted, in the presence of sulfur, giving in all the cases the four possible isomers in equimolecular amounts. The reaction between acetophenone and 3,3-dimethylbutan-2-one, in the presence of sulfur, gave the thiophene **1** (36% conversion) together with the imine of 3,3-dimethylbutan-2-one (47% conversion), not being observed any thiophene with two different substituents. Then, to conduct the selectivity of the process, equimolecular amounts of imine **18** and 3-methoxyacetophenone were combined with sulfur, in the presence of **bcmim-Cl** (10 mol-%), obtaining again a mixture of the different isomers. Probably, both reactants equilibrate initially giving a mixture of both possible imines what resulted in the formation of the different thiophenes, being not possible to direct the selectivity under the studied conditions.



Scheme 5. Synthesis of thiophenes from two different ketones (acetophenone and 3-methoxyacetophenone) meditated by the **bcmim-Cl**. In parentheses, conversion determined by GC analysis.

Conclusion

In conclusion, a robust, simple, and effective process to synthesize thiophenes, starting from two ketones and elemental sulfur, has been developed by means of the use of 1,3-bis(carboxymethyl)imidazolium chloride (**bcmim-Cl**) as a heterogeneous catalyst. Different aryl methyl ketones proved to be effective reactants under the optimal conditions, giving the corresponding 2,4-disubstituted thiophene derivatives. Furthermore, the catalyst allows to use cycloalkanones as precursors in the reaction, expanding the applicability of this methodology to the preparation of polycyclic compounds. Regarding the structural design, the moieties in this metal-free catalyst provide favorable interactions with the reactants allowing the reaction to be performed under solvent-less conditions and without inert atmosphere. This fact is significant for the sustainability of the synthetic protocol. Thus, the protocol described allows the preparation of potentially interesting bioactive compounds, in preparative scale, and with an *E-factor* (7.4) in the low range of the Fine Chemical production. Moreover, the heterogeneous catalyst (employed in 10 mol%) is easily recovered and reused (with a slight decrease in activity) taking in advantage the "solid" state of the catalyst throughout the process.

Experimental Section

Instruments and reagents. All commercially available reagents and solvents were purchased (Acros, Aldrich, Fluka, Fluorochem, Merck) and used without further purification. ^{1}H NMR and ^{13}C NMR spectra were recorded at the technical service of the University of Alicante (SSTTI-UA), employing a Bruker AC-300 or a Bruker Advance-400.[§] Chemical shifts (δ) are given in ppm and the coupling constants (*J*) in Hz. Melting points were determined using a Gallenkamp capillary melting point apparatus (model MPD 350 BM 2.5) and are uncorrected. Low-resolution mass spectra (EI) were obtained at 70 eV with an Agilent 5973 Network spectrometer, with fragment ions *m/z* reported with relative intensities (%) in parentheses. Infrared spectra were recorded with an FT-IR/4100 LE (JASCO, Pike Miracle ATR) spectrometer. Spectra were recorded from neat samples and results are given in cm^{-1}. Analytical TLC was performed on Merck aluminium sheets with silica gel 60 F254, 0.2 mm thick. Silica gel 60 (0.04-0.06 mm) was employed for column chromatography. P/UV254 silica gel with $CaSO_4$ supported on glass plates was employed for preparative TLC. The conversion of the reactions and purity of the products were determined by GC analysis using a Younglin 6100GC, equipped with a flame ionization detector and a Phenomenex ZB-5MS column (5% PH-ME siloxane): 30 m (length), 0.25 mm (inner diameter) and 0.25 µm (film).

General procedure for thiophenes synthesis. A mixture of ketone (1 mmol), elemental sulfur (1.5 mmol, 48 mg), aniline (0.25 mmol, 22 µL) and **bcmim-Cl** (10 mol%, 11 mg) were put in a reaction flask and heated at 120 ºC for 6 or 16 hours. After completion of the reaction, the crude mixture was stirred vigorously with ethyl acetate (5 mL), then filtered. Other portions of ethyl acetate (2×5 mL) were used to remove thoroughly all the soluble compounds from the solid residue. The solvent was removed under vacuum, and the residue was usually purified by flash silica gel column chromatography (*n*-hexane/TBME) or preparative TLC, to give the corresponding thiophene.

2,4-Diphenylthiophene (1).[34] Yellow solid; purification by column chromatography (*n*-hexane/TBME 9.8/0.2), 95% yield (112.1 mg); m.p.: 118-119 °C (CH_2Cl_2) (Lit:[35] 120-120.5 ºC); IR (ATR): ν = 3055, 1596, 1486, 1447, 1364, 1199, 1074, 1028, 965, 885, 834, 752, 735 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ_H = 7.67-7.59 (m, 5H, 5×CH_{Ar}), 7.44-7.37 (m, 5H, 5×CH_{Ar}), 7.33-7.24 (m, 2H, SCH_{Ar} and $SCCH_{Ar}$) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 145.2, 143.3, 136.0, 134.5, 129.1, 129.0, 127.8, 127.4, 126.5, 126.0, 122.5, 119.9 ppm; MS (EI): *m/z* 237 (M^++1, 18%), 236 (M^+, 100), 234 (13).

2,4-Bis(4-fluorophenyl)thiophene (2).[20] White solid; purification by column chromatography (*n*-hexane/TBME 9.8/0.2), 87% yield (118.5 mg); m.p.: 127-128 °C (EtOAc) (Lit:[36] 124-124.5 ºC); IR (ATR): ν = 1475, 1408, 1237, 1075, 1006, 963, 885, 847, 840, 813, 749, 730, 704 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ_H = 7.62-7.54, 7.45-7.45, 7.31-7.30 (3m, 4H, 1H and 1H, 4×CH_{Ar}, SCH_{Ar} and $SCCH_{Ar}$), 7.13-7.06 (m, 4H, 4×CH_{Ar}) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 162.6 (d, *J* = 247.7 Hz), 162.4 (d, *J* = 246.7 Hz), 144.3, 142.3, 132.1 (d, *J* = 3.0 Hz), 130.6 (d, *J* = 3.2 Hz), 128.0 (d, *J* = 7.9 Hz), 127.7 (d, *J* = 8.2 Hz), 122.4, 119.5, 116.1 (d, *J* = 21.5 Hz), 115.9 (d, *J* = 21.1 Hz) ppm; MS (EI): *m/z* 274 (M^+, 6%), 273 (M^+-1, 19), 272 (100), 227 (12).

2,4-Bis(4-chlorophenyl)thiophene (3).[20] White solid; purification by column chromatography (*n*-hexane/TBME 9.8/0.2), 73% yield (111.4 mg); m.p.: 147-148 °C (EtOAc) (Lit:[36] 140 ºC); IR (ATR): ν = 1480, 1414, 1238, 1202, 1092, 1011, 962, 886, 830, 815, 750, 706, 667 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ_H = 7.55-7.48, 7.38-7.34 (2m, 5H and 5H, 8×CH_{Ar}, SCH_{Ar} and $SCCH_{Ar}$) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 144.2, 142.1, 134.2, 133.7, 133.3, 132.8, 129.2, 129.1, 127.6, 127.1, 122.5, 120.4 ppm; MS (EI): *m/z* 308 (M^++3, 15%), 307 (M^++2, 12), 306 (M^++1, 72), 305 (M^+, 20), 304 (100), 234 (18), 189 (11).

2,4-Bis(4-bromophenyl)thiophene (4).[20] White solid; purification by column chromatography (*n*-hexane/TBME 9.8/0.2), 60% yield (118.2 mg); m.p.: 172-173 °C (EtOAc) (Lit:[36] 173.5-174.5 ºC); IR (ATR): ν = 1474, 1407,

1235, 1074, 1008, 965, 887, 840, 810, 750, 729, 705 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ_H = 7.55-7.45, 7.40-7.38 (2m, 9H and 1H, 8×CH_{Ar}, SCH_{Ar} and $SCCH_{Ar}$) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 144.3, 142.2, 134.7, 133.2, 132.2, 132.1, 128.0, 127.5, 122.5, 121.9, 121.5, 120.5 ppm; MS (EI): *m/z* 237 (M^++1, 52%), 236 (M^+, 18), 393 (100), 392 (49), 189 (14), 117 (15).

2,4-Bis(3-chlorophenyl)thiophene (5).[20] White solid; purification by column chromatography (*n*-hexane/TBME 9.8/0.2), 84% yield (128.2 mg); m.p.: 85-86 °C (EtOAc); IR (ATR): ν = 1593, 1569, 1473, 1096, 1078, 902, 874, 837, 777, 742, 734, 681 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ_H = 7.62-7.57 (m, 2H, 2×CH_{Ar}), 7.54 (d, *J* = 1.5 Hz, 1H, $SCCH_{Ar}$), 7.51-7.42 (m, 2H, 2×CH_{Ar}), 7.41 (d, *J* =1.5 Hz, 1H, SCH_{Ar}), 7.36-7.24 (m, 4H, 2×CH_{Ar}) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 143.9, 141.9, 137.4, 135.9, 135.0, 134.9, 130.3, 130.2, 127.9, 127.5, 126.5, 125.9, 124.5, 124.1, 122.9, 121.2 ppm; MS (EI): *m/z* 308 (M^++3, 14%), 307 (M^++2, 13), 306 (M^++1, 71), 305 (M^+, 18), 304 (M^+-1, 100), 234 (16).

2,4-Bis(2-chlorophenyl)thiophene (6).[20] Yellow oil; purification by column chromatography (*n*-hexane/TBME 9.8/0.2), 67% yield (102.3 mg); IR (ATR): ν = 903, 725 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ_H = 7.61-7.57 (m, 2H, CH_{Ar} and $SCCH_{Ar}$), 7.51-7.39 (m, 4H, SCH_{Ar} and 3×CH_{Ar}), 7.32-7.24 (m, 4H, 4×CH_{Ar}) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): mixture of two rotamers displayed δ_C = 141.0, 139.7, 139.5, 135.5, 133.1, 132.6, 132.5, 131.5, 131.4, 131.2, 130.8, 130.7, 130.4, 129.6, 128.9, 128.85, 128.7, 127.9, 127.1, 127.05, 125.0 ppm; MS (EI): *m/z* 308 (M^++3, 15%), 307 (M^++2, 13), 306 (M^++1, 70), 305 (M^+, 18), 304 (M^+-1, 100), 234 (25), 116 (19).

2,4-Bis(2-bromophenyl)thiophene (7). Yellow oil; purification by column chromatography (*n*-hexane/TBME 9.8/0.2), 52% yield (102.5 mg); IR (ATR): ν = 2359, 2341, 1461, 1433, 1024, 906, 751, 732 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ_H = 7.68 (td, *J* = 7.8 and 1.6 Hz, 2H, 2×CH_{Ar}), 7.57-7.50 (m, 2H, 2×CH_{Ar}), 7.45 (dd, *J* = 7.4 and 1.6 Hz, 2H, $SCCH_{Ar}$ and CH_{Ar}), 7.35 (td, *J* = 7.8 and 1.3 Hz, 2H, SCH_{Ar} and CH_{Ar}), 7.19 (tt, *J* = 7.4 and 1.6 Hz, 2H, 2×CH_{Ar}) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): mixture of two rotamers displayed δ_C = 142.5, 141.2, 141.1, 137.5, 135.2, 133.9, 133.6, 132.05, 132.0, 131.4, 129.8, 129.3, 129.2, 128.9, 127.8, 127.65, 127.6, 124.7, 122.9, 122.7 ppm; MS (EI): *m/z* 396 (M^++2, 10%), 395 (M^++1, 55), 394 (M^+, 100), 392 (M^+-1, 52), 234 (42), 232 (11), 202 (11), 189 (20). HRMS (GC/MS-EI/Q-TOF) calcd. for $C_{16}H_{10}Br_2S$ 391.8870, found 391.8874.

2,4-Bis[4-(trifluoromethyl)phenyl]thiophene (8).[37] Yellow solid; purification by column chromatography (*n*-hexane/TBME 9.8/0.2), 37% yield (68.9 mg); m.p.: 136-137 °C (EtOAc); IR (ATR): ν = 2926, 1600, 1546, 1491, 1234, 1160, 1101, 1012, 888, 821, 799, 749, 710 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ_H = 7.67-7.51 (m, 4H, 4×CH_{Ar}), 7.45 (d, 1H, $SCCH_{Ar}$), 7.30 (d, 1H, $SCCH_{Ar}$), 7.13-7.06 (m, 4H, 4×CH_{Ar}) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 143.9, 142.0, 138.8, 137.3, 129.8 (q, *J* = 32.6 Hz), 129.5 (q, *J* = 32.6 Hz), 126.5, 126.0 (q, *J* = 3.8 Hz), 125.9, 125.85 (q, *J* = 3.9 Hz), 124.0 (q, *J* = 255 Hz), 123.9 (q, *J* = 255 Hz), 123.3, 122.4 ppm; MS (EI): *m/z* 274 (M^+, 6%), 273 (M^+-1, 19), 272 (100), 227 (12).

2,4-Bis(4-methylphenyl)thiophene (9).[20] White solid; purification by column chromatography (*n*-hexane/TBME 9.8/0.2), 83% yield (109.7 mg); m.p.: 147-148 °C (EtOAc) (Lit:[38] 145 ºC); IR (ATR): ν = 3022, 2913, 2857, 1547, 1498, 1375, 1124, 1017, 887, 848, 808, 784, 748 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ_H = 7.55-7.50, 7.24-7.22 (2m, 5H and 1H, 4×CH_{Ar}, SCH_{Ar} and $SCCH_{Ar}$), 7.21-7.18 (m, 4H, 4×CH_{Ar}) 2.37 (s, 6H, 2×CH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 145.2, 143.2, 137.7, 137.1, 133.3, 131.8, 129.7, 129.6, 126.3, 125.9, 122.0, 118.7, 21.35, 21.3 ppm; MS (EI): *m/z* 265 (M^++1, 21%), 264 (M^+, 100), 263 (M^+-1, 21).

2,4-Bis(2-methylphenyl)thiophene (10). Colorless oil; purification by column chromatography (*n*-hexane/TBME 9.8/0.2), 64% yield (84.6 mg); IR (ATR): ν = 2952, 2359, 2342, 1481, 1457, 1379, 1191, 1116, 1035, 907, 757, 732 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ_H = 7.51-7.43 (m, 1H, CH_{Ar}), 7.40-7.35 (m, 1H, CH_{Ar}), 7.29-7.22 (m, 6H, 6×CH_{Ar}), 7.19 (d, *J* = 1.5 Hz, 1H, $SCCH_{Ar}$), 7.12 (d, *J* = 1.5 Hz, 1H, SCH_{Ar}), 2.47 (s, 3H, CH_3), 2.40 (s, 3H, CH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 142.7, 142.3, 136.8, 136.2, 135.8, 134.3, 131.0, 130.7, 130.5, 129.8, 128.5, 128.0, 127.5, 126.1, 126.0, 122.5, 21.4, 21.0 ppm; MS (EI): *m/z* 265 (M^++1, 21%), 264 (M^+, 100), 231 (9), 216 (26), 215 (25), 115 (14). HRMS (GC/MS-EI/Q-TOF) calcd. for $C_{18}H_{16}S$ 264.0973, found 264.0974.

2,4-Bis(3-methylphenyl)thiophene (11). Orange oil; purification by column chromatography (*n*-hexane/TBME 9.8/0.2), 82% yield (108.4 mg); IR (ATR): ν = 2917, 1601, 1485, 1458, 1208, 1094, 899, 879, 836, 796, 781, 746, 688 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ_H = 7.57 (d, *J* = 1.5 Hz, 1H, $SCCH_{Ar}$), 7.50-7.40 (m, 4H, 4×CH_{Ar}), 7.35 (d, *J* = 1.5 Hz, 1H, SCH_{Ar}), 7.34-7.25 (m, 2H, 2×CH_{Ar}), 7.16-7.05 (m, 2H, 2×CH_{Ar}), 2.41 and 2.40 (2s, 6H, 2×CH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 145.2, 143.3, 138.7, 138.5, 136.0, 134.4, 129.0, 128.9, 128.6, 128.1, 127.2, 126.7, 123.6, 123.1, 122.4, 119.6, 21.7, 21.6 ppm; MS (EI): *m/z* 265 (M^++1, 21%), 264 (M^+, 100), 248 (5). HRMS (GC/MS-EI/Q-TOF) calcd. for $C_{18}H_{16}S$ 264.0973, found 264.0978.

2,4-Bis(3-methoxyphenyl)thiophene (12).[39] Yellow oil; purification by column chromatography (*n*-hexane/TBME 9.5/0.5), 87% yield (128.9 mg); IR (ATR): ν = 1599, 1579, 1483, 1465, 1435, 1287, 1264, 1202, 1166, 1042, 839, 778, 734 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ_H = 7.56 (d, *J* = 1.5 Hz, 1H, $SCCH_{Ar}$), 7.37 (d, *J* = 1.5 Hz, 1H, SCH_{Ar}), 7.35-7.27 (m, 2H, 2×CH_{Ar}), 7.25-7.22 (m, 2H, 2×CH_{Ar}), 7.21-7.13 (m, 2H, 2×CH_{Ar}), 6.91-6.83 (m, 2H, 2×CH_{Ar}), 3.85 (s, 6H, 2×OCH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 160.15, 160.1, 145.0, 143.1, 137.4, 135.8, 130.1, 130.0, 122.7, 120.2, 119.0, 118.6, 113.4, 112.8, 112.3, 111.7, 55.5, 55.4 ppm; MS (EI): *m/z* 296 (M^++1, 21%), (M^+, 100).

1,2,3,5,6,7-Hexahydrodicyclopenta[*b*,*d*]thiophene (13).[20] Greenish oil; purification by preparative TLC (*n*-hexane/TBME 9.8/0.2), 70% yield (57.5 mg); IR (ATR): ν = 2925, 2854, 2360, 1684, 1571, 1457, 1376, 1240, 1209, 1094, 1012, 988, 700 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ_H = 2.88-2.77 (m, 4H, 2×$SCCCH_2$), 2.64-2.59 (m, 4H, 2×2$SCCH_2$), 2.44-2.36 (m, 4H, 2×$CH_2CH_2CH_2$) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 144.8, 140.4, 29.7, 29.3, 27.5 ppm; MS (EI): *m/z* 165 (M^++1, 16%), 164 (M^+, 100), 163 (M^+-1, 86), 149 (27), 137 (30), 136 (35), 135 (28), 131 (20), 115 (11).

1,1,5,5-Tetramethyl-1,2,3,5,6,7-hexahydrodicyclopenta[*b*,*d*]thiophene (14). Yellow oil; purification by preparative TLC (*n*-hexane/TBME 9.9/0.1), 41% yield (45.2 mg); IR (ATR): ν = 2952, 2925, 2849, 2360, 2335, 1708, 1460, 1363, 1253, 1184, 739 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ_H = 2.67 (s, 3H, CH_2 and C*H*H), 2.63-2.57 (m, 1H, C*H*H), 2.43-2.41 (m, 3H, CH_2 and C*H*H), 2.23-2.18 (m, 1H, C*H*H), 1.29 (s, 3H, CH_3), 1.22 (s, 9H, 3×CH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 142.1, 139.2, 130.5, 121.8, 45.55, 45.5, 45.1, 45.0, 43.1, 43.0, 30.45, 30.4, 29.8, 26.4 ppm; MS (EI): *m/z* 220 (M^+, 19%), 206 (14), 205 (100). HRMS (GC/MS-EI/Q-TOF) calcd. for $C_{14}H_{20}S$ 220.1286, found 220.1280.

1,2,3,4,6,7,8,9-Octahydrodibenzo[*b*,*d*]thiophene (15).[20] Yellow oil; purification by preparative TLC (*n*-hexane/TBME 9.9/0.1), 34% yield (32.7 mg); IR (ATR): ν = 2924, 2854, 2839, 1665, 1444, 1335, 1293, 1262, 1115, 1067, 1027, 816, 737 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ_H = 2.71-2.68 (m, 4H, 2×CH_2), 2.42-2.38 (m, 4H, 2×CH_2), 1.76-1.48 (m, 8H, 4×CH_2) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 134.0, 132.0, 25.0, 24.0, 23.8, 22.7 ppm; MS (EI): *m/z* 192 (M^+, 64%), 191 (M^+-1, 31), 165 (14), 164 (100), 163 (27), 136 (17).

2,7-Dimethyl-1,2,3,4,6,7,8,9-octahydrodibenzo[*b*,*d*]thiophene (16). Colorless oil (mixture of two diastereoisomers); purification by preparative TLC (*n*-hexane/TBME 9.8/0.2), 49% yield (54.0 mg); IR (ATR): ν = 2948, 2920, 2840, 1455, 1439, 1375, 1266, 1132, 1117, 1073, 984, 831 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): mixture of two diastereoisomers, δ_H = 2.83-2.68 (m, 6H, 6×C*H*H), 2.58-2.21 (m, 8H, 8×C*H*H), 2.06-1.77 (m, 10H, 6×C*H*H and 4×CH), 1.57-1.32 (m, 4H, 4×C*H*H), 1.06 (d, 12H, *J* = 6.3 Hz, 4×CH_3) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): mixture of two diastereoisomers, δ_C = 134.1, 133.7, 132.2, 131.9, 33.4, 32.8, 32.7, 32.15, 32.1, 31.2, 31.1, 30.2,

30.15, 29.15, 29.1, 25.0, 24.0, 23.9, 22.0, 21.8 ppm; MS (EI): *m/z* 221 (M^++1, 15%), 220 (M^+, 87), 219 (M^+-1, 14), 205 (15), 179 (21), 178(100), 163 (14), 136 (34). HRMS (GC/MS-EI/Q-TOF) calcd. for $C_{14}H_{20}S$ 220.1286, found 220.1283.

5,6,12,13-Tetrahydrodinaphtho[2,1-*b*;2,1-*d*]thiophene (17). Yellow oil; purification by preparative TLC (*n*-hexane/TBME 9.9/0.1), 20% yield (28.9 mg); IR (ATR): v = 2929, 1598, 1580, 1550, 1477, 1448, 1421, 960, 862, 808, 756, 737, 682 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ_H = 7.28-7.13 (m, 8H, 4×CH_{Ar}), 3.14-3.11 (m, 4H, 2×CH_2), 3.01-2.94 (m, 4H, 2×CH_2) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ_C = 136.1, 135.8, 135.7, 133.8, 133.3, 127.9, 127.8, 127.7, 126.9, 126.8, 126.6, 126.3, 124.3, 124.1, 124.0, 123.8, 31.3, 31.2, 30.6, 29.3 ppm; MS (EI): *m/z* 289 (M^++1, 22%), 288 (M^+, 100), 287 (M^+-1, 25), 286 (19), 285 (17), 284 (19), 271 (11), 253 (11), 252 (11). HRMS (GC/MS-EI/Q-TOF) calcd. for $C_{20}H_{16}S$ 288.0973, found 288.0972.

Recycling experiments. A mixture of acetophenone (1 mmol, 120 µL), elemental sulfur (1.5 mmol, 48 mg) and aniline (0.25 mmol, 22 µL) was stirred at 120 °C in the presence of **bcmim-Cl** (10 mol%, 11 mg). Then, the catalyst was separated from the reaction mixture by centrifugation using ethyl acetate (5 mL). The catalyst was rinsed with ethyl acetate (6×5 mL), dried under vacuum and reused for the next catalytic cycle.

Acknowledgements

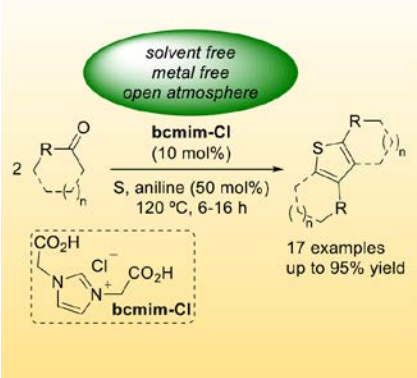
This work was financially supported by the University of Alicante (VIGROB-173, VIGROB-285, VIGROB-316FI and UAUSTI19-21), the Spanish Ministerio de Economía y Competitividad (CTQ2015-66624-P, CTQ2017-88171-P), the Spanish Ministerio de Ciencia, Innovación y Universidades (PGC2018-096616-B-I00) and the Generalitat Valenciana (AICO/2017/007). P.G. thanks the ISO (University of Alicante) for a grant.

Keywords: imidazolium salt • metal-free • sulfur • sustainable chemistry • thiophene

§ For further information of the scientific equipment, see: Research Technical Services - University of Alicante, http://sstti.ua.es/en.

[1] S. Pathania, R. K. Narang, R. K. Rawal *Eur. J. Med. Chem.* **2019**, *180*, 486-508.
[2] R. Shah, P. K. Verma *Chem. Cent. J.* **2018**, *12*, 137.
[3] F. A. Larik, M. Faisal, A. Saeed, Q. Abbas, M. A. Kazi, N. Abbas, A. A. Thebo, D. M. Khan, P. A. Channar *J. Mater. Sci. Mater. Electron.* **2018**, *29*, 17975-18010.
[4] a) D.-T. D. Tang, K. D. Collins, J. B. Ernst, F. Glorius *Angew. Chem., Int. Ed.* **2014**, *53*, 1809-1813; b) Y. Maki, T. Goto, N. Tsukada *ChemCatChem* **2016**, *8*, 699-702.
[5] S. Abbat, D. Dhaked, M. Arfeen, P. V. Bharatam *RSC Adv.* **2015**, *5*, 88353-88366.
[6] a) K. Gewald, E. Schinke, H. Boettcher *Chem. Ber.* **1966**, *99*, 94-100; b) J. M. Tinsley in *Name Reactions in Heterocyclic Chemistry*, (Eds.: J. J. Li, E. J. Corey), Wiley & Sons, Hoboken, NJ, **2005**, pp 193-198.
[7] R. J. Mullins, D. R. Williams in *Name Reactions in Heterocyclic Chemistry*, (Eds.: J. J. Li, E. J. Corey), Wiley & Sons, Hoboken, NJ, **2005**, pp 184-192.
[8] R. J. Mullins, D. R. Williams in *Name Reactions in Heterocyclic Chemistry*, (Eds.: J. J. Li, E. J. Corey), Wiley & Sons, Hoboken, NJ, **2005**, pp 199-206.
[9] R. A. Sheldon *Chem. Soc. Rev.* **2012**, *41*, 1437-1451.
[10] G. Minetto, L. F. Raveglia, A. Sega, M. Taddei *Eur. J. Org. Chem.* **2005**, 5277-5288.
[11] G. Revelant, S. Dunand, S. Hesse, G. Kirsch *Synthesis* **2011**, 2935-2940.
[12] W. You, X. Yan, Q. Liao, C. Xi *Org. Lett.* **2010**, *12*, 3930-3933.
[13] P. Fricero, L. Bialy, W. Czechtizky, M. Mendez, J. P. A. Harrity *Org. Lett.* **2018**, *20*, 198-200.
[14] A. Hassanabadi, M. R. Hosseini-Tabatabaei *J. Sulfur Chem.* **2012**, *33*, 273-277.
[15] C. R. Reddy, R. R. Valleti, M. D. Reddy *J. Org. Chem.* **2013**, *78*, 6495-6502.
[16] a) T. B. Nguyen *Asian J. Org. Chem.* **2017**, *6*, 477-491; b) T. B. Nguyen *Adv. Synth. Catal.* **2017**, *359*, 1106-1130; c) T. B. Nguyen, P. Retailleau *Org. Lett.* **2017**, *19*, 4858-4860; d) T. B. Nguyen, P. Retailleau *Org. Lett.* **2018**, *20*, 186-189; e) T. T. T. Nguyen, V. A. Le, P. Retailleau, T. B. Nguyen *Adv. Synth. Catal.* **2020**, *362*, 160-165.
[17] G. Zhang, H. Yi, H. Chen, C. Bian, C. Liu, A. Lei *Org. Lett.* **2014**, *16*, 6156-6159.
[18] L. Meng, T. Fujikawa, M. Kuwayama, Y. Segawa, K. Itami *J. Am. Chem. Soc.* **2016**, *138*, 10351-10355.
[19] Z. Wang, Z. Qu, F. Xiao, H. Huang, G.-J. Deng *Adv. Synth. Catal.* **2018**, *360*, 796-800.
[20] T. B. Nguyen, P. Retailleau *Green Chem.* **2018**, *20*, 387-390.
[21] D. A. Alonso, A. Baeza, R. Chinchilla, G. Guillena, I. M. Pastor, D. J. Ramón *Eur. J. Org. Chem.* **2016**, 612-632.
[22] a) K. Tanaka, F. Toda *Chem. Rev.* **2000**, *100*, 1025-1075; b) R. S. Varma *Green Chem.* **1999**, *1*, 43-55.
[23] A. Dhakshinamoorthy, A. M. Asiri, M. Alvaro, H. Garcia *Green Chem.* **2018**, *20*, 86-107.
[24] M. Albert-Soriano, I. M. Pastor *Eur. J. Org. Chem.* **2016**, 5180-5188.
[25] M. Albert-Soriano, P. Trillo, T. Soler, I. M. Pastor *Eur. J. Org. Chem.* **2017**, 6375-6381.
[26] P. Gisbert, I. M. Pastor *Synthesis* **2018**, *50*, 3031-3040.
[27] P. Trillo, I. M. Pastor *Adv. Synth. Catal.* **2016**, *358*, 2929-2939.
[28] M. Albert-Soriano, L. Hernández-Martínez, I. M. Pastor *ACS Sustainable Chem. Eng.* **2018**, *6*, 14063-14070.
[29] P. Gisbert, M. Albert-Soriano, I. M. Pastor *Eur. J. Org. Chem.* **2019**, 4928-4940.
[30] a) C. O. Kappe, D. Dallinger, S. S. Murphree *Practical microwave synthesis for organic chemists*. Wiley-VCH, Weinheim, **2009**; b) N. E. Leadbeater *Microwave heating as a tool for sustainable chemistry*. CRC Press, Boca Raton, **2011**.
[31] D. Prat, A. Wells, J. Hayler, H. Sneddon, C. R. McElroy, S. Abou-Shehada, P. J. Dunn *Green Chem.* **2016**, *18*, 288-296.
[32] M. Albert-Soriano, I. M. Pastor *Adv. Synth. Catal.* **2020**, doi:10/1002/adsc.202000102
[33] T. Kanzian, T. A. Nigst, A. Maier, S. Pichl, H. Mayr *Eur. J. Org. Chem.* **2009**, 6379-6385.
[34] K. Ueda, S. Yanagisawa, J. Yamaguchi, K. Itami, K. *Angew. Chem. Int. Ed.* **2010**, *49*, 8946-8949.
[35] D. C. Allport *Polymer* **1967**, *8*, 492-493.
[36] E. Campaigne, W. B. Reid, J. D. Pera *J. Org. Chem.* **1959**, *24*, 1229-1232.
[37] R. Pereira, A. Furst, B. Iglesias, P. Germain, H. Gronemeyer, A. R. de Lera *Org. Biomol. Chem.* **2006**, *4*, 4514-4525.
[38] P. Demerseman *J. Chem. Soc.* **1954**, 2720-2722.
[39] E. Bey, S. Marchais-Oberwinkler, R. Werth, M. Negri, Y. A. Al-Soud, P. Kruchten, A. Oster, M. Frotscher, B. Birk, R. W. Hartmann *J. Med. Chem.* **2008**, *51*, 6725-6739.

Thiophene synthesis



An ionic organic solid, such as 1,3-bis(carboxymethyl)imidazolium chloride, mediates metal-free thiophene derivatives syntheses by favoring the reaction under solvent-free conditions, representing an efficient and sustainable protocol.

Institute and/or researcher Twitter usernames: @impb13; @UA_Universidad